

42,603

THE
Description *and* Use
OF A
New Quadrant,
For Finding the
LATITUDE at SEA :

Invented and made, by
BENJAMIN COLE,
Mathematical and Optical INSTRUMENT-MAKER,
At the Orrery in *Fleet-Street*, *London* ;
Late the Shop of
Mr. **THOMAS WRIGHT**,
INSTRUMENT-MAKER to his MAJESTY.

The SECOND EDITION.

WITH AN
APPENDIX,
SHEWING

Some useful Improvements on COLE's Quadrant.

PARTICULARLY

• **GODFREY's** Horizon Vane improv'd.

Which furnishes the Mariner with the Means of taking
an Observation easily in boisterous Weather.

To which are added,

Short and Plain Instructions for the Use of that most
excellent Instrument, invented by *John Hadley*, Esq;
with the Improvement of an Artificial Horizon.

L O N D O N :
Printed by JOHN HART, MDCCXLIX.

1651/524.



Advertisement

SINCE the first publication of the
first volume of the "Gleaner"
it has been a source of much interest
and has been read with much pleasure
by the friends of the cause of
the oppressed. The second volume
is now ready for sale. It contains
many interesting and valuable
articles, and is well calculated
to do much good. It is sold
at the price of one shilling
per volume. The "Gleaner"
is published by the
Gleaner and Countryman
Society, 10, Abchurch Lane,
London. The price of the
second volume is one shilling
per volume. The "Gleaner"
is published by the
Gleaner and Countryman
Society, 10, Abchurch Lane,
London. The price of the
second volume is one shilling
per volume.

Advertisement.

SINCE the first Publication of my New Sea Quadrant, several Gentlemen seeing the Likeness of it at a Shop, somewhat nearer than mine to the *Royal Exchange*, have thereby mistaken that Shop for mine, which is at the *Orrery*, two Doors above the *Globe-Tavern*, and between two Picture Shops, in *Fleet-Street, London*; late the Shop of Mr. *Thomas Wright*, Instrument-Maker to his Majesty.

At which Place are made and sold *Hadley's* Quadrant, mounted either in Brass or Wood; Azimuth, Amplitude or other Compasses of all Sorts, either for Cabin, Steerage or Pocket; also half Minute Glasses, made in such a Manner as not to be affected by the Weather, but will be unalterably the same in all Climates: Likewise curious Hydrometers for ascertaining to a very great Degree of Exactness the different Strengths of Spirituous Liquors, very useful for Dealers therein: Also Telescopes of all Sorts, Pocket and other Cases of Instruments, and all other Mathematical and Optical Instruments, in the utmost Perfection, and at the most reasonable Prices.



THE
Description *and* Use,
Of a New
Sea Quadrant.

21. 4. 11.

THIS Instrument consists of six parts, *viz.* a Staff, a Quadrantal Arch, three Vanes, and a Vernier.

The Staff is a wooden bar of about a foot and a half, or two feet long, an inch and quarter broad, and of a thickness sufficient to prevent it from springing or bending.

The Quadrantal Arch is likewise of wood, and about the same strength with the small arch in the common *Davis's* Quadrants; it has fixed to its extremities, two radius's, meeting in the center at right angles: The Quadrant is joined at its center to one end of the staff, by a center pin, round which it easily moves: The arch is graduated into degrees, and third parts of a degree; to a radius

of nine inches, this length being thought sufficient ; but the Quadrant may be made to a larger radius, if required.

The Vanes are of the same nature and use as those of *Davis's Quadrant* ; but in this Instrument they are fixed, and are of brass.

The Sight Vane is fixed near that end of the staff, which is to be placed near the eye at the time of using.

The Horizon Vane is fixed to the center pin, round which the Quadrant turns.

The Shade Vane stands on the upper radius of the Quadrant.

The Vernier is a scale of equal parts, serving to divide the degrees on the Quadrant into minutes ; it is placed on the staff, so that the arch slides against it, and thereby the degrees and minutes of altitude, are cut by the said Vernier.

Explanation of the Figure.

ac	—	Represents the staff.
abd	—	The Quadrant.
bd	—	The Quadrantal Arch.
a	—	The fix'd Center Pin.
a	—	The Place of the Horizon Vane.
b	—	— the Shade Vane.
c	—	— the Sight Vane.
e	—	— the Vernier.

To



To find the Sun's Altitude by this Instrument.

Turn your back to the sun; with the right hand hold the Instrument, by the staff, so that it be in a vertical plane passing thro' the sun; apply the eye to the Sight Vane, look thro' that and the slit in the Horizon Vane, until you see the horizon; with the left hand slide the Quadrantal Arch upwards, until the solar shade, or spot, cast by the Shade Vane, falls directly on the slit or spot in the Horizon Vane: Then shall that part of the Quadrantal Arch, which is raised above the staff, shew the altitude of the sun at that time.

When altitudes, or heights, above the horizon are taken, reckon from the upper limb downwards: But when the complements of altitudes, or zenith distances are to be taken; reckon the degrees and minutes from the lower limb upwards.

And this may suffice for the general description and use: But because there are several particulars wherein this Instrument greatly exceeds *Davis's Quadrant*, it will be proper to annex a farther explanation of the parts.

Of

Of the Sight Vane.

It is a thin plate of brass, near two inches high, and one broad, set perpendicularly on the staff at one end, being pin'd down by two screws passing thro' its foot; in this Vane is drilled a fine hole in the middle, about an inch and a third above the plane of the Instrument, and is counter-sunk, or opened wider, on the outside: Thro' this hole, is to be viewed the coincidence, or meeting, of the horizon and solar spot.

Of the Horizon Vane.

This Vane is near an inch broad, and about two inches and a half high; it has a slit cut thro' it of about an inch long, and a quarter of an inch broad; the upper part of the slit, is near an inch and three quarters above the plane of the Instrument, to which the Vane stands perpendicular, and by its foot, is fixed, with two screws, to the head of the center pin; whereby its position to the sight Vane is kept the same; their inclination is at an angle of 45 degrees.

Of

Of the Shade Vane.

This Vane consists of two brass plates; the one, which serves as an arm, is about four inches and a half long, and three quarters of an inch broad; it is pinned at one end to the upper limb of the Quadrant, by a screw, about which it has a small motion; the other end lying on the arch; the lower edge of the arm lies directed to the middle of the center pin: The other plate, which is properly the Vane, is about two inches long, and fixed perpendicular to the arm, at about half an inch distant from that end next the arch; this Vane may be used, either by its shade, or by the solar spot cast by a convex lens, or glass set therein. In the back of the arm, is a pin, which passes thro' a hole in the limb of the Quadrant; this pin is acted on by the end of a screw, whereby the arm moves on its center; and that the arm may remain steady, it is pressed against, on one side, by a spiral spring, which holds it tight against the screw on the other side: The use of this contrivance, is to adjust the Vane to the Instrument, so that when the 0 deg. against the upper limb of the Quadrant, is set against the line marked G on the Vernier, then the hole in the
sight

sight Vane, the center of the glass, and the sunk spot in the horizon Vane, may all lie in a right line. This precaution is absolutely necessary, because the wood work is sometimes apt to twist or warp.

The construction here described of the shade Vane, may perhaps be sometimes altered for the better; for as there are many ways to effect the same end, the best may not always present itself till after many trials.

Of the Arch.

This arch contains 100 degrees, *viz.* 5 deg. on each side of the Quadrant: The quadrantal Arch is numbered both ways, *viz.* beginning at 0 deg. on the upper limb, they proceed to 90 deg. on the lower limb; where beginning with 0 deg. they run on to 90 deg. on the upper limb; every tenth degree is numbered; and the single degrees are distinguished by lines drawn across three arches: each degree is divided into three equal parts, and distinguished by lines drawn across the two outward arches, so that the arch of the Instrument is divided into parts of 20 minutes each; and every single minute will be discovered by means of the Vernier; against which, the arch is held tight, by a spring fixed to the staff, under the arch; whereby the Quadrant, by its weight alone, will not swing

be divided into 6 equal parts, B into 5 equal parts.

Here 3 are the primary divisions, 6 and 5 are the secondary ones. Then $(\frac{B}{5} - \frac{A}{6} = \frac{3}{5 \times 6} =)$ one tenth of an inch is the excess of one secondary part of B, above one of the secondary parts of A.

II. *If the lengths of two arches A and B, be each equal to 7 degrees, and A be again divided into 21 parts, and B into 20 parts.*

Then $(\frac{B}{20} - \frac{A}{21} = \frac{7}{2 \times 21} = \frac{1}{20 \times 3} =)$ one sixtieth of a degree, is the excess of one of the parts of B, above one of the parts of A.

This kind of division is of such a nature, that if a line C, be taken equal to several times the length of the line A, and be divided into as many of the secondary divisions of A, as it will contain; then if the line B moves along the line C, one of the divisions of C, will always coincide with one of the divisions of B; and by these means it is, that minutes of a degree are to be reckoned on the arch of this Quadrant. For here, the distance of the two outside divisions of the Vernier, from S to 20, is equal to 10 degrees on the arch; viz. from S to 10 is 3 degrees and a half; from 10 to 10, is 3 degrees; from 10 to 20 is 3 degrees and a half; but the distance from 10 to 10, is of no other use than to make the intervals from the middle, G to S, and from G to 20,

each equal to 5 degrees, for a reason that will be shewn hereafter; therefore the breadth of the 20 divisions on the Vernier, supposing 10 and 10 to be brought close to each other, is equal to 7 degrees on the arch; now each degree on the arch is divided into 3 equal parts, therefore the 7 degrees is divided into 21 equal parts; but in two arches, each of 7 degrees, one being divided into 21 equal parts, and the other into 20, then by these divisions, one sixtieth of a degree, or one minute, will be ascertained, as is evident by the second of the foregoing examples.

That the young Navigator, for whom these pages are principally intended, may be readily able to count the degrees and minutes on this instrument, some instructions for that purpose here follow.

I. *When the glass Vane is to be used.*

Set 0 degrees, on the upper, or vane limb of the Quadrant, against the line marked G on the Vernier; then the arch being raised any number of whole degrees, the line G will cut those degrees: If the arch be raised any number of degrees, and 20 minutes, or 40 minutes; then will the line G cut the first, or second division between the degrees, reckoning from the upper to the lower limb: If the arch be raised to degrees, and any number of minutes, the line G will always stand
against

against the part so raised, reckoning the minutes between the twenties, on the Vernier. Thus, if the arch was raised 30 deg. 15 min. then the line G would stand between the division of 30 deg. and 20 min. and the division 15 on the Vernier, and no other, will stand against a division on the arch.

If the line G stood between the 20th and 40th minutes, lying between the 35th and 36th degrees; and the 12th division only on the Vernier, stood against a division on the arch, then would the Quadrant be raised to $35^{\circ} 32'$

Also if G stood after $35^{\circ} 40'$; and the 8th division on the Vernier, cut a division on the arch; then would the Quadrant be elevated $35^{\circ} 48'$. And the like is to be understood of other degrees and minutes.

II. *When the shade Vane is to be used.*

Instead of using the line G, use the line marked S; and then the former directions will suit this line, only changing G for S.

Thus, if the line S stood between 43 deg. and 43 deg. 20 min. and the 10th division on the Vernier, cut a division on the arch; then would the Quadrant be rais'd to $43^{\circ} 10'$.

If the S stood after $43^{\circ} 20'$, and the 16th division on the Vernier, cut a division on the arch; then is the Quadrant raised to $43^{\circ} 36'$
And

And if S stood after $56^{\circ} 40'$, and the 5th division on the Vernier cut a division on the arch, the Quadrant would be elevated $56^{\circ} 45'$. And the like for other elevations.

To observe, with either the glass, or shade Vane.

Look thro' the hole in the sight Vane; raise or depress the instrument, until the horizon appears thro' the slit in the horizon Vane; keep it in this position; move the arch on its center, until the bright spot cast by the glass from the sun, falls on the hole in the horizon Vane, the horizon itself appearing at the same time thro' the slit; then will the degrees and minutes cut by the line G on the Vernier, shew the height of the sun at that time.

If the sun is very bright, it may be most convenient to use the shade Vane, and this is the strait side of the same Vane wherein the glass is set: To use this, move the arch until the shade cast by the upper edge of the Vane falls on the hole in the horizon Vane, the eye at the same time seeing thro' the sight Vane, the shade meeting the horizon seen thro' the slit; then will the degrees and minutes cut by the line S on the Vernier, shew the height of the sun at that time.

When the shade Vane is used, subtract 16 minutes from the height given by the line S;

swing round the center, but stand at whatever degree it is elevated to; and that it may remain in this position, there is a screw at the back of the staff, which by turning will press the arch so tight against the Vernier, that its position cannot be easily altered, should it be thought necessary to preserve it.

Of the Vernier.

The outward edge of the Quadrantal Arch, slides under the chamfer'd or sloped edge of a piece of wood or brass, which is pinned to the staff: On this piece is a scale of divisions, serving to cut the degrees on the arch into single minutes; and is called *Vernier's Division* (from its inventor;) and therefore, for distinction, the piece on which the scale is put, is called the Vernier.

Although a scale thus divided, is commonly called *Nonius's Division*; yet *Nonius* was not the inventor thereof; for in two treatises of *Peter Nonius*, one published, *An. 1572*, concerning the twilight; and the other, *An. 1592*, about Navigation, he describes a method of ascertaining small parts of a degree, but very different from that which passes under his name; and moreover, it was a method so liable to uncertainty and

B

error,

error, that the great *Tycho Brake* rejected it, after having given it a tryal in his astronomical instruments. — The scale commonly called a *Nonius*, such as is used to this new Sea Quadrant, and in most other instruments designed to measure angular positions, was invented by *Peter Vernier*, a gentleman of *Franch Comte*, and described by him, in the *French* tongue, in a Treatise on a new Quadrant, published at *Brussels*, *An.* 1631. therefore, to do justice to the inventor, the name of this scale, or division, should be changed from that of *Nonius*, to *Vernier*; and this would not be difficult to accomplish, were workmen to be informed of the equity of the change.

The principle, on which *Peter Vernier* founded his division, is; that in two equal lines A and B, each consisting of the same number of primary divisions, if they be again divided into any other number of equal parts, provided the number of the secondary parts in A, be one more than the number of the secondary parts of B; then will one of the latter parts of B, exceed one of the latter parts of A, by such a part of A, as will be expressed, by dividing the number of the primary parts in one, by the product of the number of the secondary parts in both A and B.

Examples

- I. If A and B, be each of 3 inches; and A
be

S; because the sun, at a mean, is 32 minutes in diameter; and it is the upper edge thereof which corresponds with the shade.

As the edge of this shade Vane is 5 degrees higher than the center of the glass; therefore the line marked S, is five degrees below the line marked G.

The directions already given for the taking of the sun's altitude at sea, would be sufficient, were it not for two corrections necessary to be made, before the altitude can be accurately assign'd; the first of these arises on account of the eye being elevated above the plane of the horizon; and the second on account of the refraction occasioned by the haziness of the atmosphere in small altitudes.

Of the correction on elevation.

When the eye is above the surface of the sea, it sees an horizon below the true one belonging to that place; therefore the sun will appear more elevated than its true height, by as much as the observed horizon dips below the true one; therefore this dip of the horizon must be taken from the observed altitude.

As the height of the eye above the surface of the water, may vary according to the size or loftiness of the ship; therefore here is inserted a table shewing the minutes which are to be taken from the observed altitude.

This

This table is computed on the supposition of the earth being spherical, and that its diameter is 43946552 English feet; for so much will be the diameter of a Sphere equal to that figure which is assigned to the earth by the latest observations.

Of the correction on refraction.

The haziness (or vapours) in the Atmosphere, causes the sun to appear higher than what it is, and therefore the observed altitude must be diminished by as much as is the refraction on that altitude. These refractions have been collected by the experience of eminent men; and so far as observations at sea may be affected thereby, is inserted in a table hereto annexed.

And because the corrections of altitude may appear at sight, therefore the horizontal dips, and refractions, are joined together in the same page.

These corrections ought to be made in every observation of altitude at Sea, whether the altitude is taken with this instrument, or *Davis's Quadrant*, or *Hadley's Quadrant*, or any other Instrument whatever.

A T A B L E, shewing the corrections to be made to altitudes taken at sea, on account of the height of the eye above the horizon, and of the refraction of the atmosphere.

Heights of the eye.	Correc- tions.	Altitud. observ'd.	Correc- tions.	Altitude observ'd.	Correc- tions.
Feet.	Minut.	Degrees.	Minut.	Degrees.	Minut.
5	$2\frac{1}{2}$	1	23	12	$4\frac{1}{2}$
10	$3\frac{1}{2}$	2	$17\frac{1}{2}$	15	$3\frac{1}{2}$
15	4	3	$13\frac{1}{2}$	20	$2\frac{1}{2}$
20	$4\frac{1}{2}$	4	$11\frac{1}{2}$	25	2
25	$5\frac{1}{2}$	5	9 $\frac{1}{2}$	30	$1\frac{1}{2}$
30	$5\frac{1}{2}$	6	8	35	$1\frac{1}{2}$
35	$6\frac{1}{2}$	7	7	40	1
40	$6\frac{1}{2}$	8	$6\frac{1}{2}$	50	$0\frac{1}{2}$
45	7	9	$5\frac{1}{2}$	60	$0\frac{1}{2}$
50	$7\frac{1}{2}$	10	5	70	$0\frac{1}{2}$

Example.

Suppose the eye is 30 feet higher than the water, and the sun's altitude was observed to be 25 degrees.

Against 30 feet high is $5\frac{1}{2}$ Min.
min. call it ——— 6

Against 25 deg. altitude is ——— 2

Their sum ——— 8 Minutes,

Taken from the observed

altitude ——— $25^{\circ} 00'$

Leaves for the correct ———

altitude ——— $24^{\circ} 52'$

Note. These corrections are to be added to Zenith distances,

C

As

As this Quadrant is proposed to be used instead of *Davis's*; it will be convenient to shew wherein this has the advantage.

In *Davis's* Quadrant, if the long bar A B should warp or twist; or if the bar D be not of its exact length; then in either case, the arches will not correspond to each other; and consequently, the observation will be inaccurate. Inconveniencies of this kind are avoided in the new Quadrant; because its construction is more simple, and the parts are less dependant on each other. Besides, the probability of the arches being distorted, either thro' themselves, or by the limbs A E, A C, in *Davis's* Quadrant, is much greater than in this instrument.

In *Davis's* Quadrant, as the sight Vane is moved upwards or downwards, the slit in the horizon Vane, appears of different apertures: Also, if the sight Vane is to be moved, the Quadrant must be taken from the eye, which is a loss of time; and sometimes by the wood swelling, the Vane moves so hard, that 'tis difficult to fix it to its proper place; at other times the vanes will be so slack as to fall off, and perhaps be lost; these faults and accidents to which the common vanes are liable, besides that of their unavoidable length and splitting, are perfectly remedied in this instrument; where the vanes being fix'd, there is very little probability of losing them, and they will
preserve

preserve a due position to each other in all altitudes; besides the time employ'd in moving the common vanes, frequently occasions the loss of an observation; this can never happen in the use of the new Quadrant, whose arch can be easily moved at the same time the eye is looking thro' both the sight and horizon vanes.

The shade vane in this new Quadrant, can be so adjusted, as that its center shall fall in a right line, drawn from the sight vane to the horizon vane; whereby this instrument will be preserved from those errors so frequently complain'd of in *Davis's* Quadrant, of being too much to the Northward, or to the Southward; that is, of giving the Latitude too great or too little. Besides, in this, there is no preparation to fix the shade vane, by guessing at the zenith distance, which is a necessary article in the use of the other Quadrant.

Another very great advantage which this new Quadrant has over *Davis's*, arises from the manner of its divisions; whereby the accuracy of the degrees, and parts of degrees on the quadrantal arch, may easily be examined from end to end; for by sliding the arch by the vernier, it will be easy to see whether the like number of degrees, &c. on the arch correspond to the same divisions on the vernier, in all positions of the Quadrant: Such an examination, cannot be so easily per-

formed in diagonal divisions, which may be very incorrect, although they appear to be well executed.

Notwithstanding the simplicity and correctness of *Vernier's* division, (or, as commonly call'd, *Nonius's*;) diagonals are still used in some instruments for taking of angles; because there have been, and may be still, persons who prefer the latter to the former: But the most eminent and accurate Astronomers, have admitted the division of *Vernier* on their chief instruments, and rejected the method of diagonals, * as being perswaded of the superiority of the other.

Lastly, to all these advantages, may be added, that the price of this instrument will not be greater than that of *Davis's* Quadrant; so that the seaman may have it in his power, to furnish himself with a Quadrant, that will exceed *Davis's* in every respect, and not cost him more money.

To fit this instrument for observing the altitude of the sun, when the horizon cannot be seen.

To the Staff of the Quadrant let there be

* The method of dividing of arches into small parts, by the help of diagonals, was invented by Richard Chanseler, an Englishman, as related by Thomas Digges, Esq; in a treatise on mathematical scales, printed at London, Anno 1573.

fixed a spirit level, † whose axis must be parallel to a line supposed to be drawn thro' the centers of the sight and horizon vanes; and then the instrument is fitted for observation without an horizon.

To observe the sun's altitude by the Quadrant thus prepared.

Sit down on the deck, with the right hand towards the sun; let the staff rest on both knees, holding it with the right hand; move the knees so, to humour the ship's motion, that the bubble in the spirit level plays about the middle of the tube, or as much on one side of the mark as on the other: With the left hand, move the arch until the spot or shade cast by the shade vane, falls on the spot in the horizon vane: Now, if it be observed, that the bubble plays in the middle, at the same time the solar mark falls on the spot in the horizon vane, then that part of

† In a cylindric glass tube, pour so much spirit of wine as will nearly fill it, and let its ends be well stopped; then if the tube be held horizontal, there will be a bubble of air standing against the middle; but if one end of the tube dips below the horizon, the bubble will always run towards the other end; and consequently will shew whether the tube be horizontal, or not so; such an instrument is called a spirit level. On each side of the middle of the tube, is commonly placed two marks, to which the extremities of the bubble will reach when the tube is horizontal.

the

the arch raised above the staff, will shew the sun's altitude at that time.

A little practice, will make an artist expert in this kind of observing by the level, or artificial horizon.

In using the quadrant in this manner, there are no allowances to be made for the height of the eye above the water.

This instrument may be easily applied to the setting of cannon or mortars to any degree of elevation; by taking off the sight vane; and also the level from the end of the staff, and applying it to the limb of the quadrant, which now becomes the upper limb for this use.

To elevate Artillery.

Raise the upper limb of the quadrant, until the vernier cuts the degrees and minutes proposed for the elevation; screw the arch fast in that position, put the staff into the gun, and apply its lower edge to the lower part of the chafe, or the upper edge to the upper part of the chafe, and hold it fast in that situation: Let the muzzle of the gun be raised, until the bubble stands in the middle of the tube: And then will that piece of artillery stand at the elevation required.



T H E
Description *and* Use
O F

HADLEY'S QUADRANT.

THIS instrument consists of the following particulars.

- I. An Octant A B C,
- II. The Index D.
- III. The Speculum E.
- IV. Two horizon glasses F and G.
- V. Two Screens K, and K.
- VI. Two sight Vanes H and I.

I. *Of the Octant.*

The Octant consists of the two radius's or limbs A B, A C; the arch B C; also, of the two braces L, M, which are to strengthen it, and prevent it from warping. The arch contains only the eighth part of the circumference of a circle, or 45 degrees, but is divided into 90 primary divisions, each of which

which stand for degrees, and are numbered 0, 10, 20, 30, &c. to 90, beginning at each end of the arch, for the convenience of counting both ways; every degree is subdivided into such parts, as will, by the help of the Index, shew the minutes of a degree.

II. *Of the Index.*

The Index D, is a flat rod or bar, moveable round the center of the instrument; that part of the Index, which slides over the graduated arch B C, is open in the middle, to see the division which are cut by a *Vernier's scale*, placed in the lower part m n, of the said opening.

Some of *Hadley's* quadrants have the arch graduated by diagonals, and the divisions in those, are determined by their interfection with a chamfered edge of the open part of the Index.

From the bottom of the Index, a piece of brass turns up against the back of the arch, in which is a screw, serving to fasten the Index against any degree of the arch.

III. *Of the Speculum.*

This is a piece of flat glass, quicksilvered on one side (like a common looking glass;) and set in a brass box: The Speculum

lum is placed perpendicular to the plane of the instrument; against the center of which, stands the middle part of the glass, whose surface or face coincides with the middle line of the Index; now the Speculum being fixed to the Index, the former will change its position, as the latter slides along the arch.

The use of the Speculum, is to receive the rays coming from an object; and to reflect them on one of the horizon glasses.

IV. *Of the horizon glasses.*

These glasses are two small pieces of looking glass placed on one of the limbs, with their faces turn'd obliquely to the Speculum, from whence they receive the reflex rays of observed objects.

The glass F has only its lower part quicksilvered, and set in brass work; the upper part being left transparent to view the horizon.

In the middle of the glass G, is a transparent slit, thro' which the horizon is to be seen.

Both of these glasses are so mounted in their brass work, as to be turned round by handles at the back of the instrument; And also, to have their perpendicular position altered; which is done by the means of three screws passing through their feet.

The convenience of altering the position of these glasses is of very great use; for

D

should

should they be thrown out of their true posture by the warping of the wood work, they can very easily be set right again; and thereby prevent those complaints, made of other instruments, of being northerly, or southerly; as giving the latitude too great, or too little.

V. *Of the Screens.*

In the two brass square frames K, K, are set pieces of coloured glass, which are to serve as Screens; the one is tinged much deeper than the other; the frames move on the same center, whereby they may be used separately, or together; in the place where they appear in the figure, they serve for the horizon glass F: But when they are wanted for the glass G, they are to be taken from their present place, and slipt into a hole on the limb above G, as at r.

The use of these glasses, is to take off the glare of the sun's rays, which might otherwise be too strong for the eye: And when the sun can be but faintly seen thro' the clouds, then either, or both, of the screens are to be turned back against the edge of the limb.

VI. *Of the sight Vanes.*

These are the two pieces H, I; each standing
ing

ing perpendicular to the plane of the instrument; that at H, has one hole in it, opposite to the transparent slit in the horizon glass G: The other at I, has two holes in it, the one opposite to the middle of the transparent part of the horizon glass F; and the other, rather lower than the edge of the quicksilvered part: To the back of this Vane, is a piece of brass moveable round a center, and serves to cover either of the holes.

The glasses used in this instrument have a peculiarity above a piece of common looking glass; for they ought to be free from veins, perfectly flat, and of an equal thickness throughout; for without these perfections, (which are rarely to be met with, unless carefully designed to be so,) the image of an object will not only be distorted, but will appear double; and very likely occasion an error in the observation.

There are two kinds of observations to be made by this instrument, *viz.* the back observation, and the fore one.

The back observation, is, when the back of the observer is turned towards the observed object.

The fore observation, is, when the face of the observer is directed towards the object.

Or, as there are two objects to be view'd, *viz.* the horizon, and one elevated above it; so the fore observation, is, when both

the objects are before the face of the observer; and the back observation, is, when one of them is before, and the other behind the observer.

To take the Sun's altitude.

I. *By the back observation.*

Put the stem of the screens K, K, into the hole r, and according to the faintness or strength of the sun's rays, let neither, or either, or both, of the frames of these glasses be turned close to the face of the limb; turn your back to the sun; with your left hand, hold the Instrument by the braces L, M, so that it be in a vertical position, and with the arch downwards; put the eye close to the hole in the vane H; look for the horizon thro' the transparent slit in the horizon glass G; with the right hand move the Index D, until the reflex image of the sun is seen in the quicksilvered part of the glass G, and in a line with the horizon; swing your body to and fro, and if the sun's image be observed to brush the horizon, then is the observation well made, and the degrees reckoned from that end of the arch farthest from your body, will give the sun's altitude at that time; subtracting 16 min. if the sun's lower edge be used; and adding 16 min. to the altitude when it is taken by the upper edge.

II. *By*

II. *By the fore observation.*

Fix the screens above the horizon glass F, using them according to the strength of the sun's rays; turn your face to the sun; with the right hand hold the instrument by the braces L, M, so as to be in a vertical position, with the arch downwards; put the eye close to the right hand hole in the vane I; view the horizon thro' the transparent part of the horizon glass F; at the same time, move the Index D with the left hand, until the reflex solar spot falls in with the line of the horizon; then shall the degrees on the arch, reckoned from that end next your body, give the altitude of the sun at that time; observing to add 16 min. if the sun's lower edge be used; and to subtract 16 min. when taken by the upper. In each of these observations, if the degrees be counted from the other end of the arch 'twill give the Zenith distance.

To take the altitude of a Star.

I. *By the fore observation.*

Turn back the screens; bring the Index close to the button h; thro' the vane I, look directly up at the star, and see it thro' the transparent part of the glass F, and also, at
the

the same time, see the reflex image on the quicksilvered part; keep the star's image in view, which by moving the Index from you, will slide down to the horizon seen thro' the transparent part of F; and the Index will cut the degrees of altitude.

II. *By the back observation.*

Thro' the vane H, and the transparent slit in the glass G, look directly at the star; at the same time move the Index till the image of the horizon, behind you, be seen in the quicksilvered part of G. and meets the star; and the Index will then shew the degrees of altitude.

Note, In all these observations, the horizon dips † must be subtracted in fore observations, and added in back ones.

To each of the horizon glasses, there is, on the back of the Instrument, a brass handle, which is governed by two screws; that in the middle of the handle screws it fast; but if slackned a little, the arm may be moved by the other screw, and the glass will turn forwards or backwards, as the screw is moved.

To rectify the Instrument.

I. *For the fore observation.*

Slacken the screw in the middle of the handle behind the glass F; bring the Index

† See p. 17.

close to the button h; hold the instrument vertical, with the arch downwards; look thro' the right hand hole in the vane I, and, thro' the transparent part of the glass F, observe the horizon; Now if it lies in the same strait line with the image of the horizon seen on the quicksilvered part, then is the glass F truly adjusted. But if the two horizon lines do not agree; turn the screw at the end of the handle backwards, or forwards, as there is occasion, until those lines coincide; fasten the middle screw of the handle, and then is the horizon glass adjusted.

II. *For the back observation.*

Slacken the screw in the middle of the handle behind the glass G; turn the button h, on one side, and bring the Index as many degrees before o, as is twice the dip of the horizon on your height above the water; hold the instrument vertical, with the arch downwards, look thro' the hole in the vane H, and if the horizon seen thro' the transparent slit in the glass G, coincides with the image of the horizon seen in the quicksilvered part of the same glass, then is the glass G in its proper position. If not, set it so by the handle,

Of the artificial horizon to Hadley's Quadrant,

To the back of the Quadrant is fitted a flat tin box; part of which goes between the limbs, and is fastened to them by two hooks
and

and eyes, so that it may be put on and off at pleasure: In the round head of this box, there hang two circles, horizontally, and joined together in the same manner, as are those circles to which the sea compass hangs, commonly called *jamballs*; to these circles is fastened a pendulum, whose leaden bob swings in the lower part of the box; from the top of the pendulum rod, and at right angles to it, comes an arm, which passeth thro' one side of the round head of the box; this arm carries a sight, or vane, which plays up and down against the horizon glass F. it being only fitted for the fore observation, which indeed performs all that is wanted of the instrument.

To observe with the artificial horizon.

Use the Quadrant in the same manner as in the fore observation; and when the hair of the vane is observed, thro' the transparent part of the glass F, to stand against the solar image, seen in the quicksilvered part, then is the observation made.

But if, by the rolling of the ship, the vane will not stand steady; observe when the hair plays as much above the image as below it, and then the observation is made.

When the horizon is hazy and cannot be well discerned, this pendulum will furnish the mariner with one; and although the observation may not be perfectly correct, yet it will give the altitude, at sea, as true as is commonly found by most Quadrants when there is a well defined horizon: And this may suffice, as an apology, for attempting to join this contrivance to an instrument, every way else so well considered.

F I N I S.



A P P E N D I X.

SINCE the publication of the foregoing sheets, and the Instrument therein described; there has appeared a Pamphlet shewing the Use, &c. of a New Sea Quadrant, which the publisher, Mr. *A*— delivers to the public as one of his own invention: As this Action of his does very much interfere with my affairs, I hope the unprejudiced Reader will excuse me for examining the right Mr. *A*— has to the invention which he thus ascribes to himself.

About five or six years ago, I made a Gunner's Quadrant, for the elevating of Artillery to given Altitudes; the Quadrantal part whereof moved round its center, which was pinned to one end of the strait stock, or bar, used to put into the Mouth of the Piece, as shewn in page 22 preceding; and I believe is the only Gunner's Quadrant yet made in that manner; Those in common use, being nothing more than a Quadrant having one of its limbs lengthened beyond the Arch, to serve as a stock to go into the gun or mortar: Some little time after I had made the said instrument, I thought it might be commodiously

modiously applied to the business of taking solar altitudes at sea: I was deterred from making it public at that time, because I conceived that the majority of Mariners were strongly prejudiced against introducing any thing novel into their practice: But having lately communicated my thoughts to some persons who were good judges of nautical affairs, I was advised not to delay its publication any longer, and accordingly I presented it to the public in *June* last: This is an exact account of the manner in which this instrument first came to my thoughts; in the construction and description thereof, I have not borrowed from any person, and therefore may justly reckon myself the Inventor; not that I conceive it to be a matter of very great importance, but because I think it a piece of injustice for any person to assume that to himself which is the property of others: This premis'd, I shall inquire into the part which Mr. *A*— has in the invention and description of the instrument which he would persuade the world is the fruit of his brain.

He begins his book by asserting, that the Quadrants then in use at sea, were either too imperfect, or too expensive; recounts some inconveniencies in *Davis's* Quadrant, and *Godfrey's* Mariner's Bow; and concludes his introduction by telling the Reader, he immediately saw that all the imperfections in
the

the Bow might be provided against, which gave birth to the Quadrant under consideration.

The first part of his assertion is not true; for several of my Quadrants were then at sea; with which an observation could be made, as accurate as by that which he calls his own; and were sold at a less price.

The inconveniencies attending *Davis's* Quadrant, such as he mentions, are all copied from other writers; and he ought as well to have marked his quotations from the *Philosophical Transactions* N^o 435, as from *Harris's* Navigation.

It was not at all difficult for him to see how imperfections in Marine Instruments could be provided against, when the provision was already known, and in use; neither is it difficult to see, by comparing his instrument and book with those which I published; that had not Mr. *Godfrey* and myself provided against the imperfections Mr. *A*— complains of, they might for him have still remain'd as obstacles to the accuracy of sea observations.

*The Particulars of Mr. Cole's and Mr. A—'s
Instruments compared.*

1. In each, the arch is about 10 inches Radius, and moves round its center.
2. In each, the arch contains 100 degrees, and each degree divided into third parts.

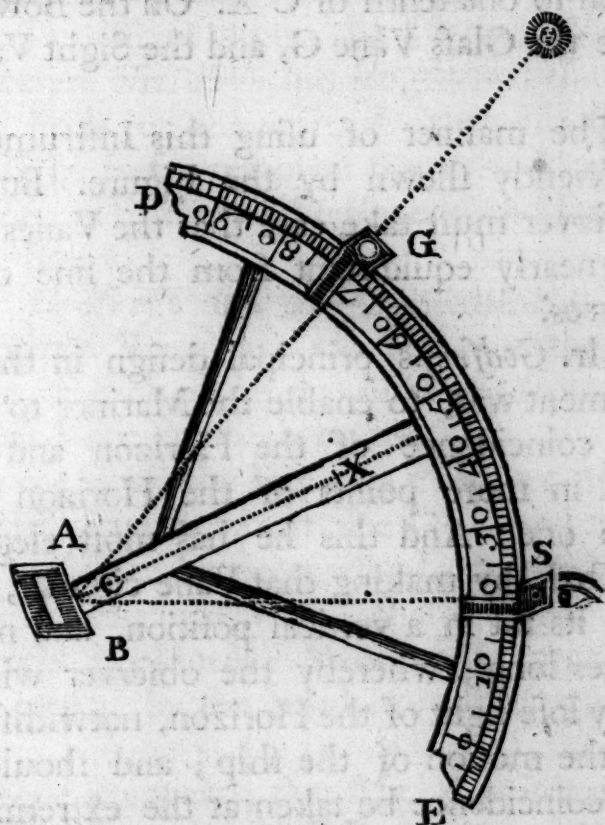
3. In each, the center of the arch is pinned to one end of a bar or Index, about 18 inches long; and on the other end is fixed the brass sight Vane.
4. In each, the arch slides against a scale of divisions (commonly called *Nonius's*) fixed to the Index; and thereby shews the minutes of altitude between the degrees.
5. In each, the Shade or Glass Vane, is fix'd on the upper limb of the Quadrant.
6. In each, the Horizon Vane is placed on the center, round which the Quadrant moves.
7. With each, the altitude of the sun is taken by the same operation.

As the foregoing are all or most of the articles concern'd in these Instruments, the above comparison is sufficient to shew their identity; therefore none of these articles were first thought on by Mr. A——; consequently it is injustice in him to impose himself on the World for the inventor of them.

If it should be objected, that in the 5th and 6th articles there are very material differences between the Instruments, and in which, the superiority of Mr. A——'s principally consist. I grant him the advantages on account of these differences, which is to facilitate the observation in boisterous seas. But then I deny that he is the inventor of that

that which gives such advantage; and this will clearly appear from what follows.

The Description of Mr. Godfrey's Mariners Bow; taken from the Philosophical Transactions, N^o 345, Anno 1734.



The Bow, or Arch D E, contains about 100 Degrees, viz. about 5 degrees on each side of the Quadrant: the middle line of the Bar, or Radius C X, cuts 45 degrees on the Arch D E: at the end C of the Radius C X, is placed the Horizon Vane A B, with its middle part C exactly at the center of the arch

arch D E, and perpendicular to the line of 45 degrees; this Vane is circular, and its Radius is to the Radius of the arch D E, as 64 is to 100; and its breadth is such, that CA, CB, is each one twentieth of the Radius C X; so that the whole breadth A B is equal to one tenth of C X. On the Bow D E, slide the Glass Vane G, and the Sight Vane S.

The manner of using this Instrument is sufficiently shewn by the Figure. But the Observer must take care that the Vanes G, S, are nearly equidistant from the line of 45 degrees.

Mr. *Godfrey's* principal design in this instrument was, to enable the Mariner to catch the coincidence of the Horizon and solar spot in more points of the Horizon Vane than one: And this he has most elegantly effected, by making that Vane circular, putting its slit in a vertical position, and near 2 inches long; whereby the observer will not easily lose sight of the Horizon, notwithstanding the motion of the ship; and should the said coincidence be taken at the extremity of the Horizon Vane, that is, at near an inch from its middle, yet the error in Altitude would not amount to one minute of a degree; and the nearer the middle of the Vane, or Center of the Bow, the coincidence falls, the error would be the less. The principles upon which Mr. *Godfrey* constructed this

In-

Instrument, is explained in the said Transaction.

A comparison between some articles in Mr. Godfrey's Bow, and in Mr. A—'s Quadrant.

1. In the Bow, the Glass and Sight Vanes are equally distant from the Horizon Vane; therefore Mr. A— has lengthened the upper limb of the arch, so that his Glass shall be as far removed from the Horizon Vane, as is the Sight Vane at the End of the Index.
2. In *Godfrey's* and A—'s instruments the Horizon Vanes are circular, and the Radius of each, is to its distance from the Glass Vane, as 64 is to 100.
3. In the Bow, the line of 45 degrees, or the middle line between the Glass and Sight Vanes, is to be perpendicular to the curve of the Horizon Vane; therefore Mr A— directs his Horizon Vane to be turned on its center, by the hand, to a like position.

Hence it appears, that Mr. A— is not the Inventer of any of these Particulars, wherein consist the advantage which the instrument he published, had over mine: And from the above comparisons, it is sufficiently evident, that he has no share in the invention of the said instrument, it being no other than my
Qua-

Quadrant, with the addition of Mr. *Godfrey's* Horizon Vane.

Within a few days after my Quadrant appeared, I was informed by Mr. *Benjamin Robins*, F. R. S. that the Instrument would have been better, had I added to it the curved Horizon Vane invented by Mr. *Godfrey*, with a proper contrivance for shifting it, so as to face the middle of the observed arch. Which hint I have not only improv'd, but have also contrived other things, which renders the Quadrant vastly more perfect, and not inferior to any Instrument for the same use: That improvements might be made, I was aware of before I publish'd it, as may be readily inferr'd from what I have said in page 8. But improvements or alterations by others, cannot transfer to them the right which undoubtedly I have to the Invention of this New Sea Quadrant.

I shall now proceed to shew, that Mr. *A—*, in the description of the Quadrant, has copyed from the said N^o 435, and from my Book, almost all that his Book contains.

From the Transaction, he has taken his account of the advantages which attend the circular Horizon Vane, also the numbers shewing the accuracy to which it may be depended on; and the variation in the velocity of the Sun's motion, at different Altitudes. So that the shew of Mathematical Learning

Learning, which appears in some of his pages, is the property of Mr. *Logan*, who sent the account to the Royal Society.

My Book he has imitated in several particulars, as

1. The Print: Where because I introduced as much of the figure of a man, as was necessary to shew the manner of using the instrument; and had put him into such a garb as might be supposed at sea: Therefore Mr. *A—* would have the figure of a whole Man in his Sea Dress, and wisely considering that he could best stand on his legs, has set him ashore fast asleep in the time of observation.
2. Because my book has tables of the dips of the Horizon on different elevations above the water; and of the refractions by the Atmosphere; therefore his book should have two such tables; the latter he owns to be *Flamsteed's*, but he does not tell the Reader that the former is taken from *Harris* and *Hadley*.
3. Because I had introduced in my book an account of the division commonly called *Nonius's*; therefore he would not let his book pass without a like account; but herein I cannot help taking notice, that Mr. *A—* is guilty of a very great oversight, which seems to have happened thro' ignorance, obstinacy, and impertinence,

1st, In not knowing that the division published by *Nonius*, is very different from that which is so called: 2d, In persisting to call that division *Nonius's*, only because it is known to workmen by that name: And 3d, In saying it was absurdly called *Vernier*, because *Vernier* explain'd it about 30 Years after *Nonius* died: Now as it does not appear that Mr. *A—* has seen the books of either *Nonius* or of *Vernier*, he ought to have submitted to the determination of those who had, until he could have better inform'd himself.

I imagine that by this time the Reader is sufficiently convinced, that Mr. *A—* has no right to any part of the invention, which he, in his book, ascribes to himself; and therefore I shall not tire his patience with other particulars; but I cannot well omit relating a similar circumstance, in which the said worthy Man did also engage himself.

Some years since, Mr. *Henry Baker*, F.R.S. published a Treatise on Microscopes; which was immediately pirated by Mr. *A—*, and when the bookseller enquired of him the reason for such an extraordinary proceeding, Mr. *A—* laughed at the question, and replied, *that the bookseller had not secured his property*: For it seems that by some mistake, Mr. *Baker's* Book was not entered at the Stationers

Stationers Hall, of which Mr. A— had cunningly informed himself.

An Account of the Improvements which I have made to this Quadrant since its first Publication.

First, To the Bar, or Index, carrying the sight Vane, is fixed a handle; whereby the observer can hold it with much more advantage than without one.

Secondly, In order to use *Godfrey's* Horizon Vane, the upper limb of the Quadrant is so lengthened that the Glass Vane at its end, is at the same distance from the center, as is the Sight Vane: There is also care taken to put it in the power of the observer very easily to set the Glass, so that its Axis shall be directed to the center of the Instrument, should it at any time be found not to point in that direction.

Thirdly, There is likewise added, Mr. *Godfrey's* circular Horizon Vane, with a contrivance which moves it so as to face the middle of the arch, intercepted between the solar and horizon Rays: This I have performed two ways by the Motion of the Index, which thereby saves the trouble of moving it by the hand; for, it is not improbable, that the article of turning this Vane into a proper position might sometimes be forgot, when left to the observer; and then

the observation would fall considerably short of its expected accuracy.

Fourthly, after having added these amendments, and considering whether there might not be made other improvements thereon; I luckily thought of applying this Quadrant to the fore observation as in *Hadley's Instrument*, which may be effected by two Methods; one way is,

On the upper limb to fix a Glass Speculum, which is to receive the Sun's direct rays, from whence they are to be reflected on a Horizon Glass fixed on the center; and to these is added a pair of skreens of colour'd glass.

The other way is, to fix the Horizon Glass on one limb of the Quadrant, a Sight Vane on the other, and the Glass Speculum on the center, just as in *Hadley's*.

This Speculum, Horizon Glass, and Screens, are of the same kind, are mounted in the same manner, and are of the same use, as are those before treated of in the description of *Hadley's Quadrant*; see pages 25, 26, &c. But as the whole arch of 90 Degrees is made use of, which was never before effected as I know of, the Radius of 9 inches becomes equal to one of *Hadley's* of 18 inches. So that my Instrument does now compleatly answer the end of *Godfrey's Bow*, *Davis's* and *Hadley's Quadrants*, and in short, of all Instruments applicable to the taking of the
Alti-

Altitudes of celestial objects at sea ; and also may be commodiously used to take the Altitude above the Horizon of any elevated object, either at Sea or on Land, as will be fully exemplified in the following directions.

*To take the Altitude of a Cælestial Object by
Cole's Quadrant.*

I. By the back Observation for the Sun.

With the right hand hold the Instrument by the handle, the back being turn'd to the Sun ; look thro' the left-hand hole in the Sight Vane, and see the Horizon thro' the vertical slit in the curved Horizon Vane : With the left hand raise the Quadrant until the solar spot falls on the Arch of the Horizon Vane, and coincides with the Horizon seen thro' the slit ; then will the Vernier shew on the Arch the degrees of the Sun's Altitude, to be reckoned on the Arch above the Index.

In rough Seas the Observer will not always be able to catch the coincidence in the middle of the curved Vane : But on whatever point thereof it falls, he may assure himself there will not be an error of one minute ; and this error will be less, the nearer to the center the coincidence is taken.

II. *By the fore Observation, for the Sun, or Star.*

Hold the Instrument as before, with the face turned to the object; look thro' the right-hand hole in the Sight Vane, and see the Horizon thro' the transparent part of the Horizon Glass; then move the Arch until the image of the Object be seen in the Horizon Glass and coincide with the Horizon seen thro' that Glass; and the Vernier will cut the degrees of Altitude.

If the Sight Vane is at the end of the Index, and the Horizon Glass at the center, then the lower part of the arch measures the Sun's Altitude, and the upper part the Zenith distance.

If the Sight Vane is fixed on one limb, the Horizon Glass on the other limb, and the Speculum on the center; with the one hand hold the long limb of the Instrument against your body; and with the other hand move the Index, until the image of the object is brought to coincide with the Horizon as before directed; then that part of the arch between your body and the Index will give the Altitude.

These Glasses are to be rectified according to the directions in p. 30, 31; and the corrections on the Sun's diameter, horizontal dips and refractions, are to be made,

ac-

according to the precepts delivered in the preceding pages.

To take the angular Altitude of a Tower, Mountain, &c. by Cole's Quadrant.

Determine some point in the elevated object on a level with your eye, which may be done by levelling the Instrument with a plummet or spirit level. Then looking thro' the Sight and Horizon Vanes to that point, move the Index until the image of the top of the elevated object, is brought to coincide with that horizontal point; and the *Vernier* will cut on the arch the degrees of elevation.

There may be other contrivances annexed to this Instrument to serve for the purposes already mentioned; and it is not impossible but better ones may offer themselves on future consideration: There may also be added a great variety of scales and divisions adapted to various uses; such as all the scales usually put on Sectors, *Gunter's*, and other rulers: It may be also particularly adapted to solve very readily all the cases of right angled plane Triangles, by putting on the back of the Index and one of the limbs, scales of equal parts, and using with them a ruler called a Tee square, having on it like scales: But as the addition of such scales would considerably increase the price of
of

of the Quadrants, therefore they will not be added but when desired.

It is not improbable, that, after the publication of my Quadrant, with the present improvements, there will be, also, a second Edition of it published by Mr. A—, which he will modestly call his own, and alledge as a pretence for so doing, that he has considerably improved it, and shew a screw, or some immaterial part different from mine; or may, perhaps, really squeeze in some advantageous alteration, a thing not impossible when the way is once shewn; the public may also by him be acquainted, that the consideration of such alteration, gave birth to the new Quadrant. If this should be the case, I shall be pleased, because the public will reap the advantage of our emulation and contest: Besides, I am conscious that all attempts to improve this Instrument, will never induce the public to confer the right of invention on any other person, than on him who first published it: This being undoubtedly the case, my Quadrant being published about the beginning of *June* last, and Mr. A—s not till the latter end of the following *September*: Therefore if any Person can improve on the Original, let him honestly publish it as Amendments, &c. to *Cole's Quadrant*. Such an Act will shew that he has the benefit of Society more at heart, than any sinister ends of his own.

F I N I S.

